Lunar Reconnaissance Orbiter

Project Overview & Status

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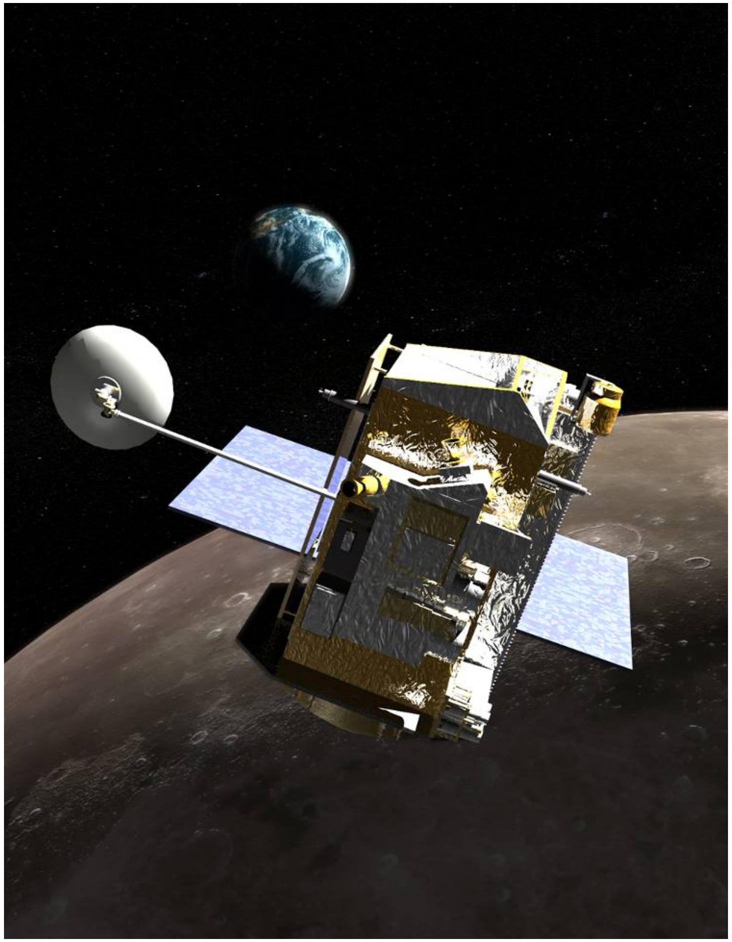
NASA Goddard Space Flight Center

http://lunar.gsfc.nasa.gov/

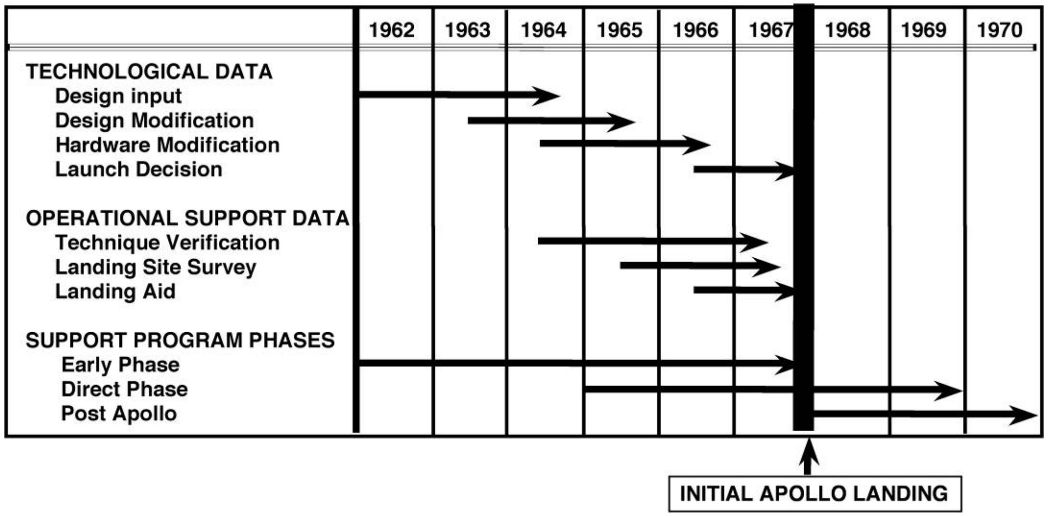
November 28, 2006



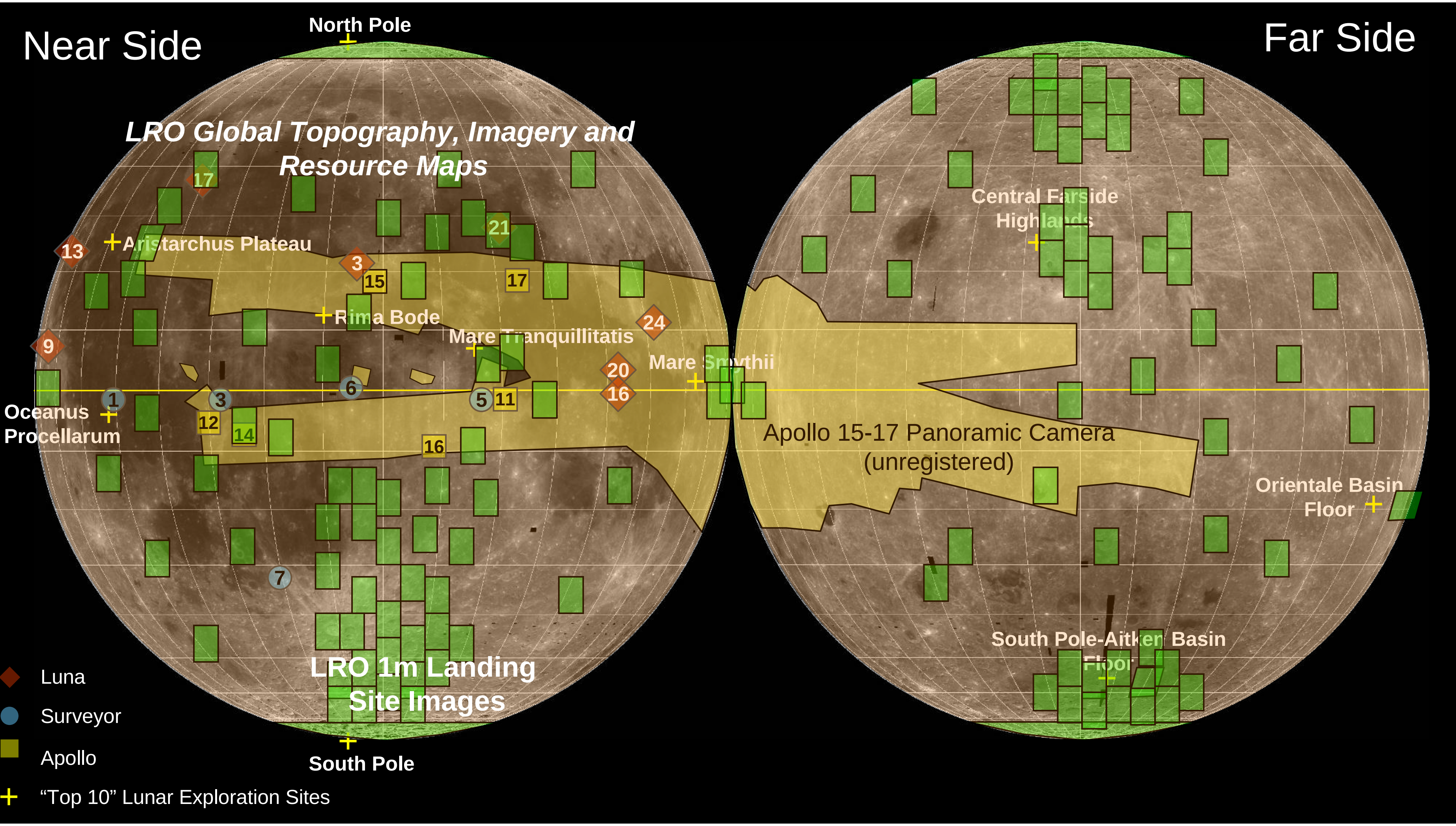
LRO Follows in the Footsteps of the Apollo Robotic Precursors

- **Apollo had three (Ranger, Lunar Orbiter and Surveyor) robotic exploration programs with 21 precursor missions from 1961-68**
  1. **Lunar Orbiters provided medium & high resolution imagery (1-2m resolution) which was acquired to support selection of Apollo and Surveyor landing sites.**
  2. **Surveyor Landers made environmental measurements including surface physical characteristics.**
  3. **Ranger hard landers took the first close-up photos of the lunar surface**
- **Exploration needs the above information to go to new sites *and* resource data to enable sustainable exploration.**

Lunar Orbiter ETU in Smithsonian Air & Space Museum, Washington DC



LRO Enables Global Lunar Surface Access



Current Apollo heritage image set only Covers 4 of 10 ESAS sites.

LRO extends coverage to entire Moon

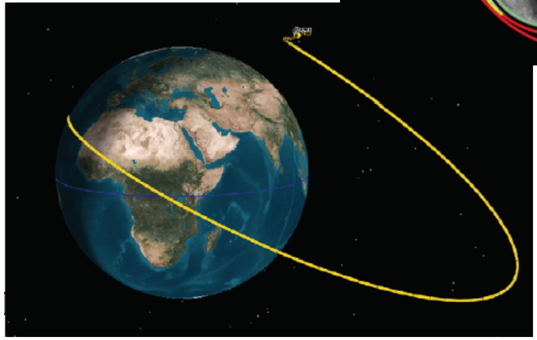
Most other high priority sites identified lie outside Apollo heritage area

LRO Mission Overview

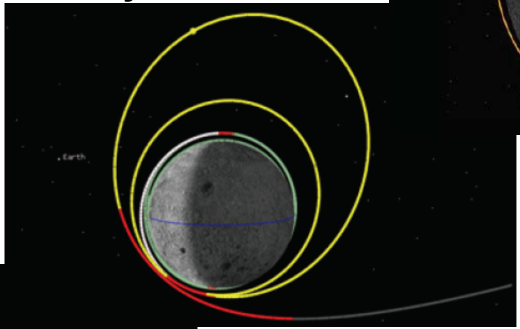
- Launch in late 2008 on a EELV into a direct insertion trajectory to the moon.
- On-board propulsion system used to capture at the moon, insert into and maintain 50 km mean altitude circular polar reconnaissance orbit.
- 1 year mission with extended mission options.
- Orbiter is a 3-axis stabilized, nadir pointed spacecraft designed to operate continuously during the primary mission.
- Investigation data products delivered to Planetary Data Systems (PDS) within 6 months of primary mission completion.

LRO Mission Overview

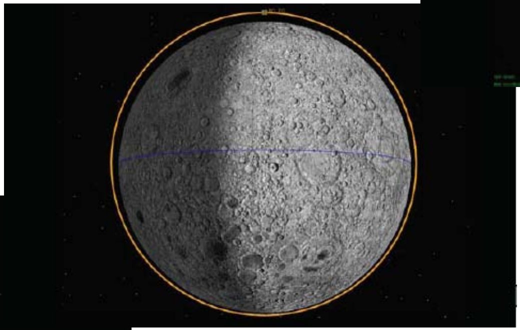
Launch: October 28, 2008



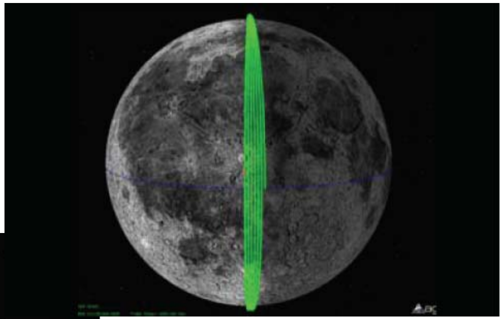
Minimum Energy Lunar Transfer ~ 4 Days



Lunar Orbit Insertion Sequence, 4 Maneuvers, 4-6 Days



Commissioning Phase, 30 x 216 km Altitude Quasi-Frozen Orbit, Up to 60 Days



Polar Mapping Phase, 50 km Altitude Circular Orbit, At least 1 Year

Nominal End of Mission: February 2010

LRO Project Implementing Organizations

NASA HQ ESMD
Level 1 Requirements

↓

NASA MSFC LPRP
Program Management

↓

GSFC LRO Project
Mission Management
Mission Operations
Spacecraft Bus
Ground Data System

KSC
Launch Services
(Lockheed Martin)

Federal Space Agency of Russia/ Russian Institute for Space Research
LEND

Southwest Research Institute
LAMP

Arizona State University/MSSS
LROC

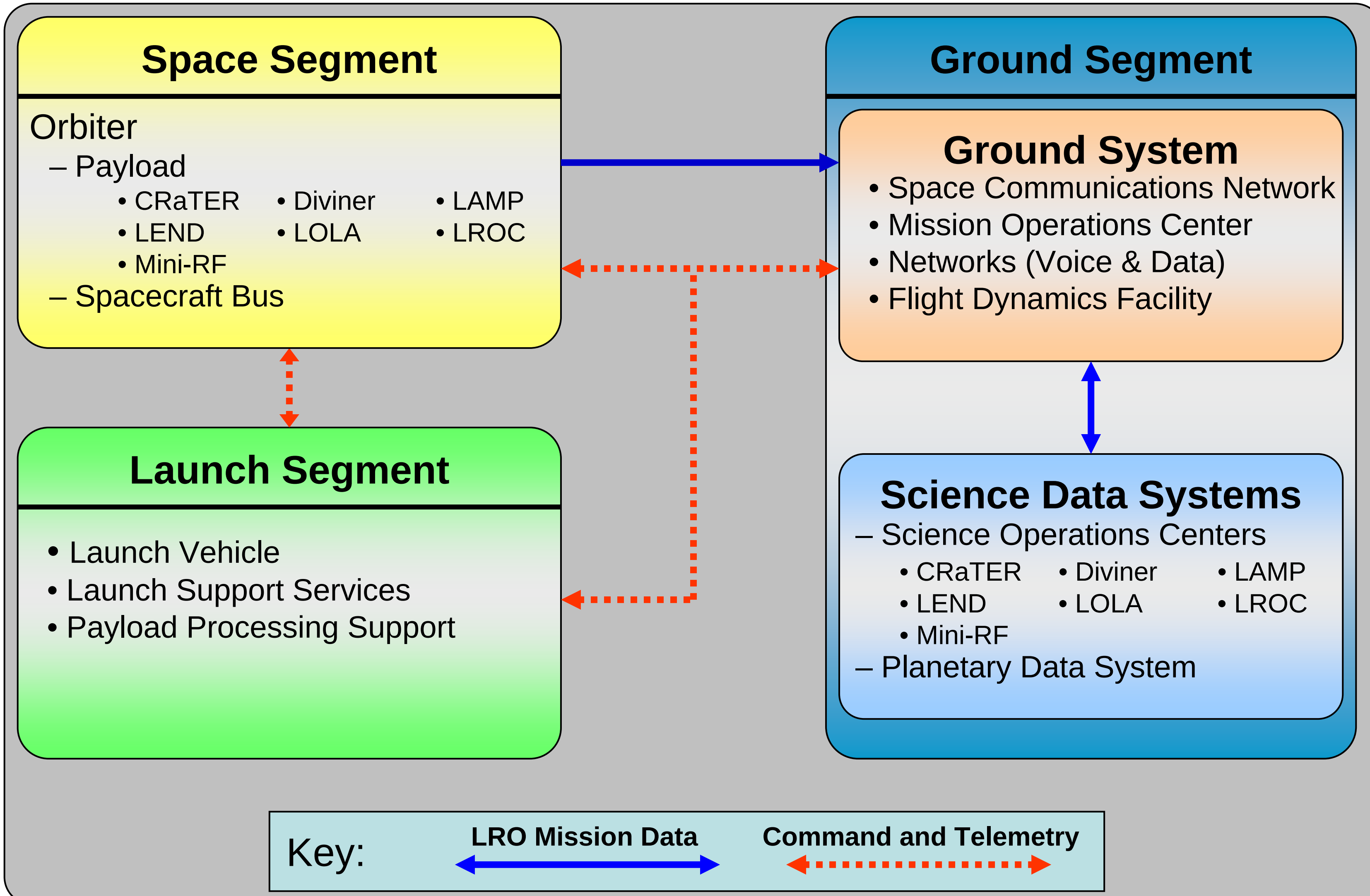
UCLA/JPL
Diviner

Boston University/MIT
CRaTER

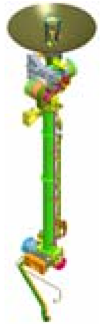
Naval Air Warfare Command/SOMD
Mini-RF

GSFC
LOLA

LRO Mission Segment Overview



LRO Spacecraft

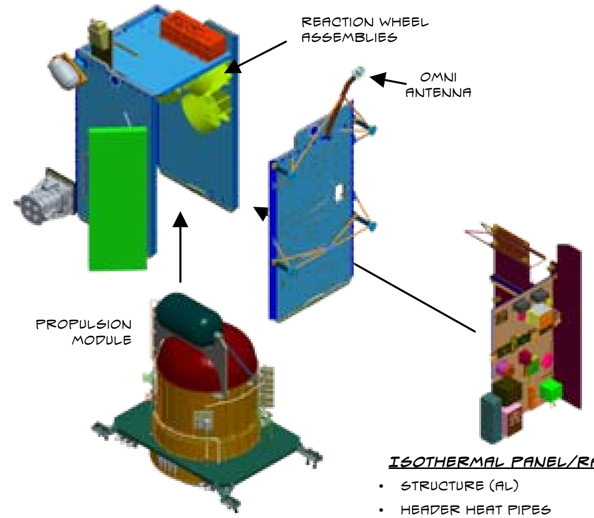


HIGH GAIN ANTENNA SYSTEM

- HIGH GAIN ANTENNA DEPLOYMENT SYSTEM
- GIMBAL SYSTEM
- GIMBAL CONTROL ELECTRONICS
- HIGH GAIN DISH ANTENNA, S-BAND PATCH ANTENNA
- LASER RANGING TELESCOPE

SPACECRAFT BUS

- PRIMARY STRUCTURE (AL)
- HGAS SUPPORT BRACKETS
- SAS STANCHIONS
- REACTION WHEEL ASSEMBLIES
- S-BAND OMNI ANTENNA

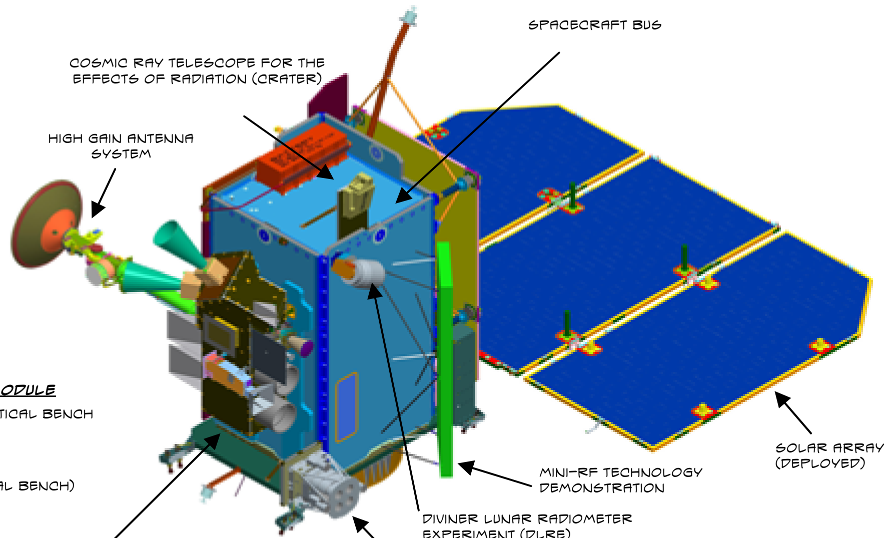


ISOTHERMAL PANEL/RADIATOR

- STRUCTURE (AL)
- HEADER HEAT PIPES
- RADIATORS (AVIONICS, BATTERY)
- S/C AVIONICS BOXES
- S/C MAIN HARNESS
- TEST CONNECTOR PANEL

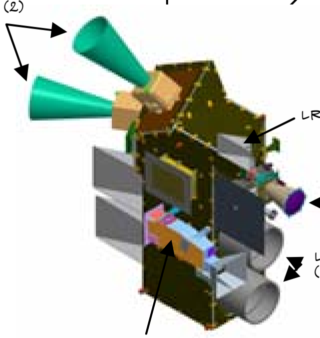
PROPULSION MODULE

- PRIMARY STRUCTURE (AL)
- TWO FUEL TANKS
- PRESSURANT TANK
- FOUR 20LB THRUSTERS, EIGHT 5LB THRUSTERS
- PROPULSION COMPONENTS/PLUMBING LINES
- S-BAND OMNI ANTENNA
- COARSE SUN SENSORS

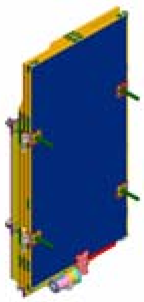


INSTRUMENT MODULE

- GRAPHITE COMPOSITE OPTICAL BENCH
- FLEXURES (TITANIUM)
- STAR TRACKERS
- INSTRUMENTS (ON OPTICAL BENCH)
  - LAMP, LOLA, LROC



LRO Orbiter Characteristics		
Mass (CBE)	1823 kg	Dry: 924 kg, Fuel: 898 kg (1263 m/sec)
Orbit Average Bus Power	681 W	
Data Volume, Max Downlink rate	459 Gb/day, 100Mb/sec	
Pointing Accuracy, Knowledge	60, 30 arc-sec	



SOLAR ARRAY SYSTEM

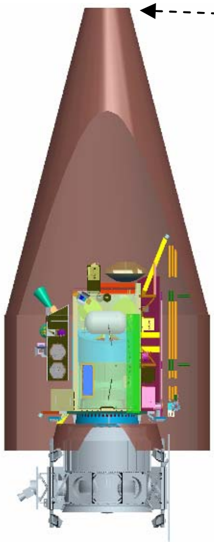
- SOLAR ARRAY DEPLOYMENT SYSTEM
- SOLAR ARRAY SUBSTRATE
- GIMBAL SYSTEM
- GIMBAL CONTROL ELECTRONICS
- COARSE SUN SENSORS

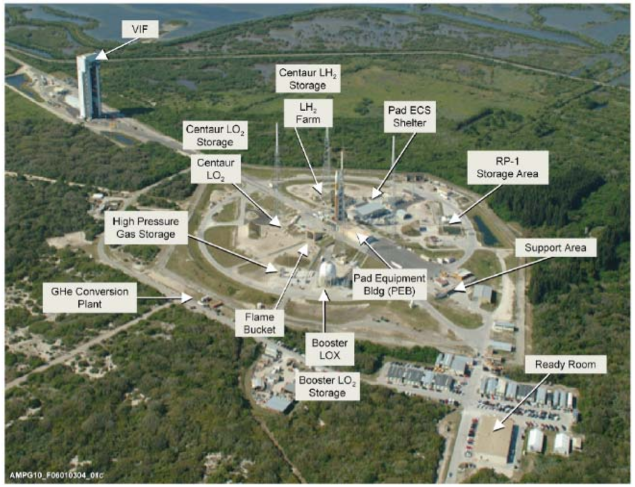
LRO Launch Segment Overview

- Launch Services Provided by KSC

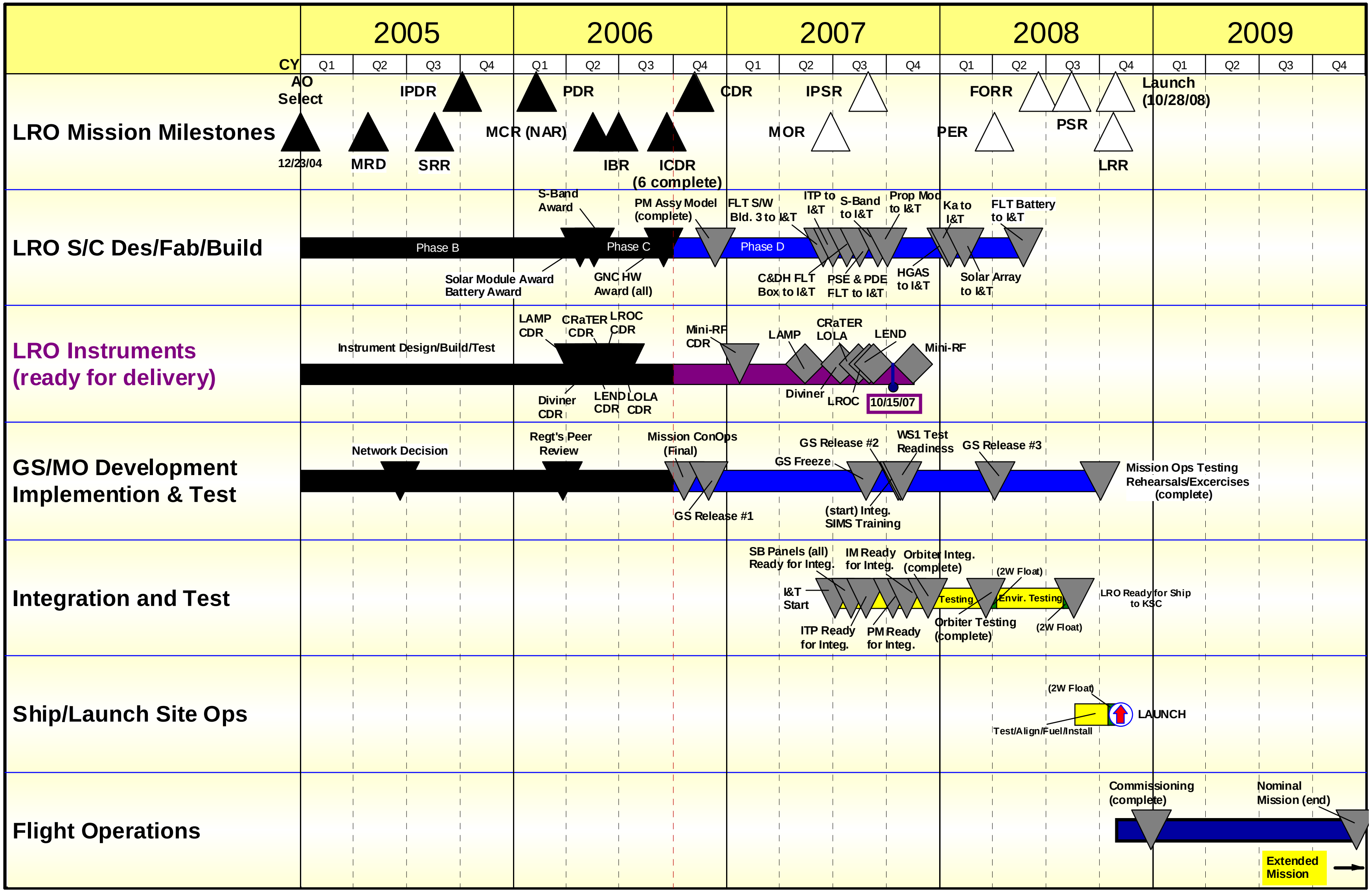
- Atlas V 401 through NLS Contract
- 2000 kg; Sun Exclusion thru Ascent
- 4m fairing; H/K data thru EELV I/F

- Launch Site Processing at Astrotech including Fueling & Control Center





LRO Mission Master Schedule



Lunar Reconnaissance Orbiter (LRO) Mission

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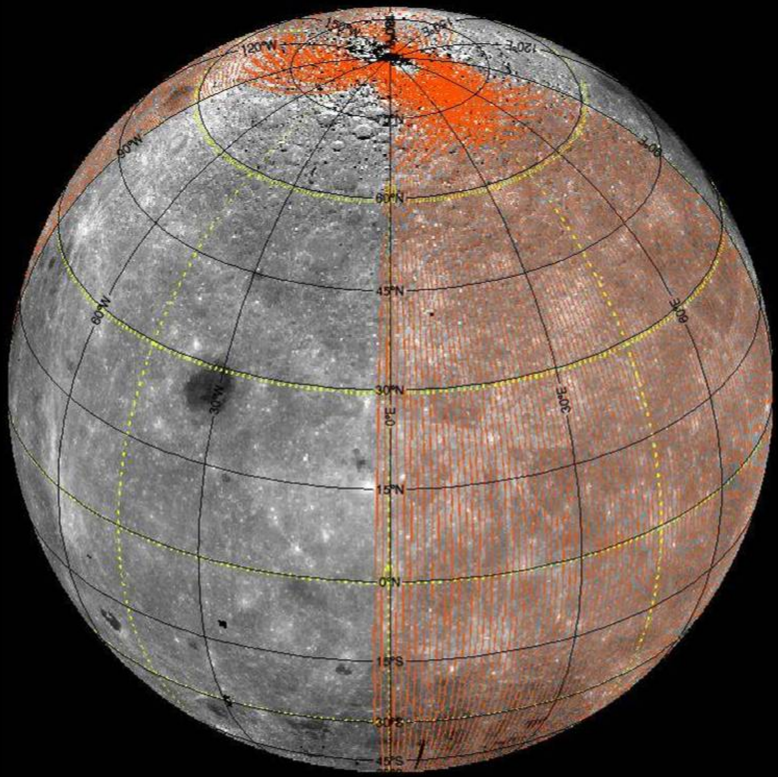
LRO Project Science Working Group
East West Center
University of Hawaii Manoa
Honolulu, Hawaii
November 28, 2006

Craig Tooley GSFC	Project Manager	Arlin Bartels GSFC	Instrument Manager
John Keller GSFC	Deputy Project Scientist	Igor Mitrofanov IKI Moscow	LEND PI
David Paige UCLA	DLRE PI	Keith Raney APL	Mini-RF POC
Mark Robinson Northwest U	LROC PI	David Smith GSFC	LOLA PI
Harlan Spence Boston U	CRaTER PI	Alan Stern SWRI	LAMP PI

Instrument & Mission Details

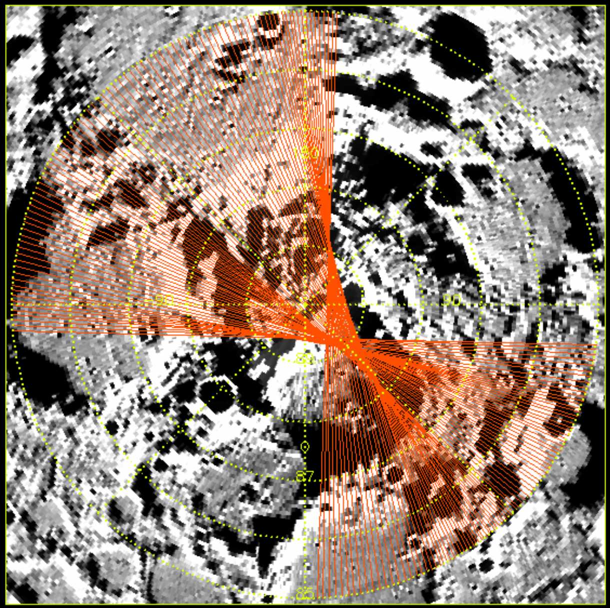
- LRO Instrument and Mission details have been input into a Space Science Review Paper, currently being reviewed prior to publication, and will be available for a pre-print viewing at the December AGU meeting
- In addition, the paper will be posted on the LRO website later this year

LRO Emphasizes the Lunar Poles

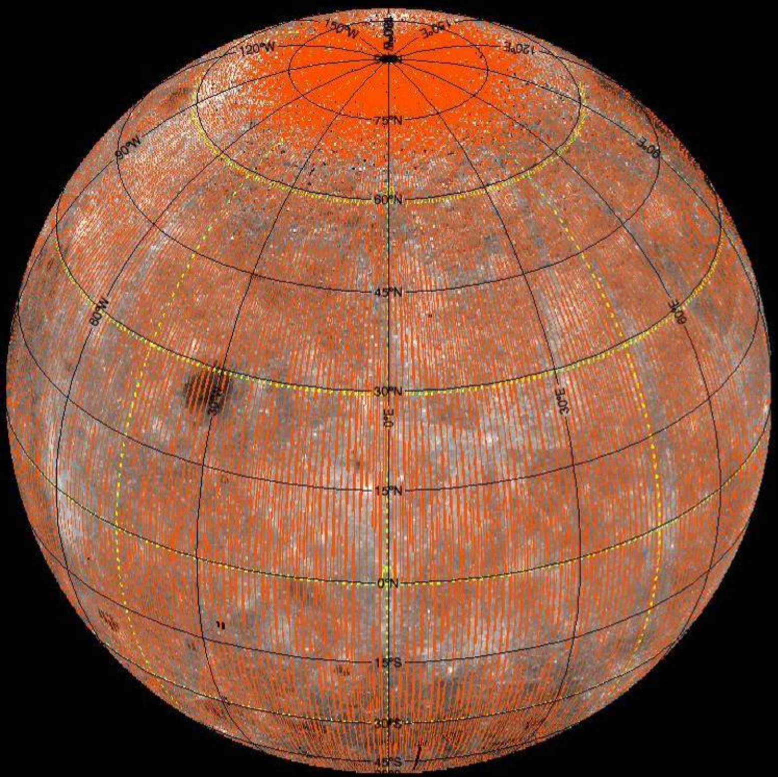


7 day orbital ground track prediction

North Pole

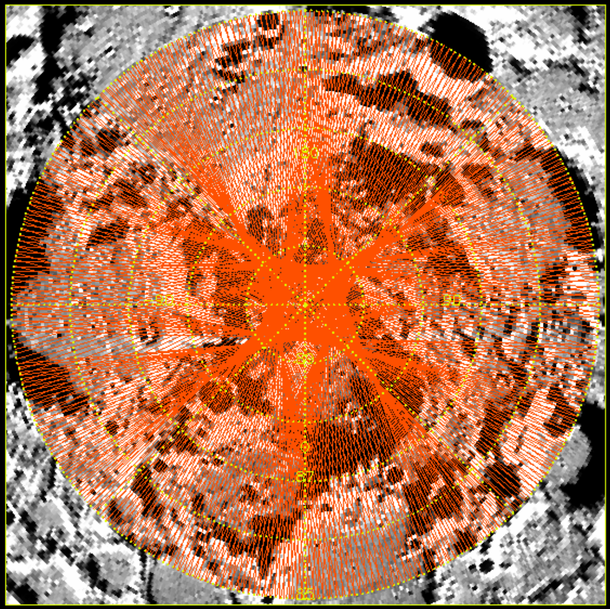


LRO Emphasizes the Lunar Poles



27 day orbital ground track prediction

North Pole



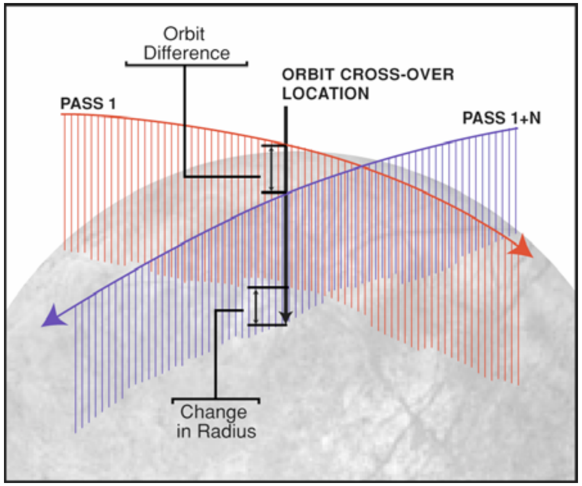
Opportunities

- Low Polar orbit will saturate the polar regions with measurement coverage at high to moderation spatial resolution observations
  - What is the complementary nature of all lunar mission data at the Poles?
  - How does preceding mission data inform near-term future missions?
- At the equator LRO ground track will have, on average, 1.2 km (average) gaps
  - How can other mission data fill in gaps; e.g. laser altimetry, imagery, etc.?

Navigation: LOLA will provide an accurate Global Lunar Reference System

- **LOLA (PI Dave Smith) will obtain an accuracy base of ~50 meters horizontal (point-to-point) and 0.5 to 1 meter radially**
  - Current accuracy ~4 km
- **LOLA is a geodetic tool to derive a precise positioning of observed features with a framework (grid) for all LRO Measurements**
  - Measure distance from LRO to the surface globally
  - Laser ranging from ground station to LRO provides precise orbit determination
  - Five laser spots along and across track
  - Measure distribution of elevation within laser footprint
  - Enhanced surface reflectance (possible water ice on surface)

- **How can other mission data sets take advantage of this improvement (Common Coordinate System breakout session)**

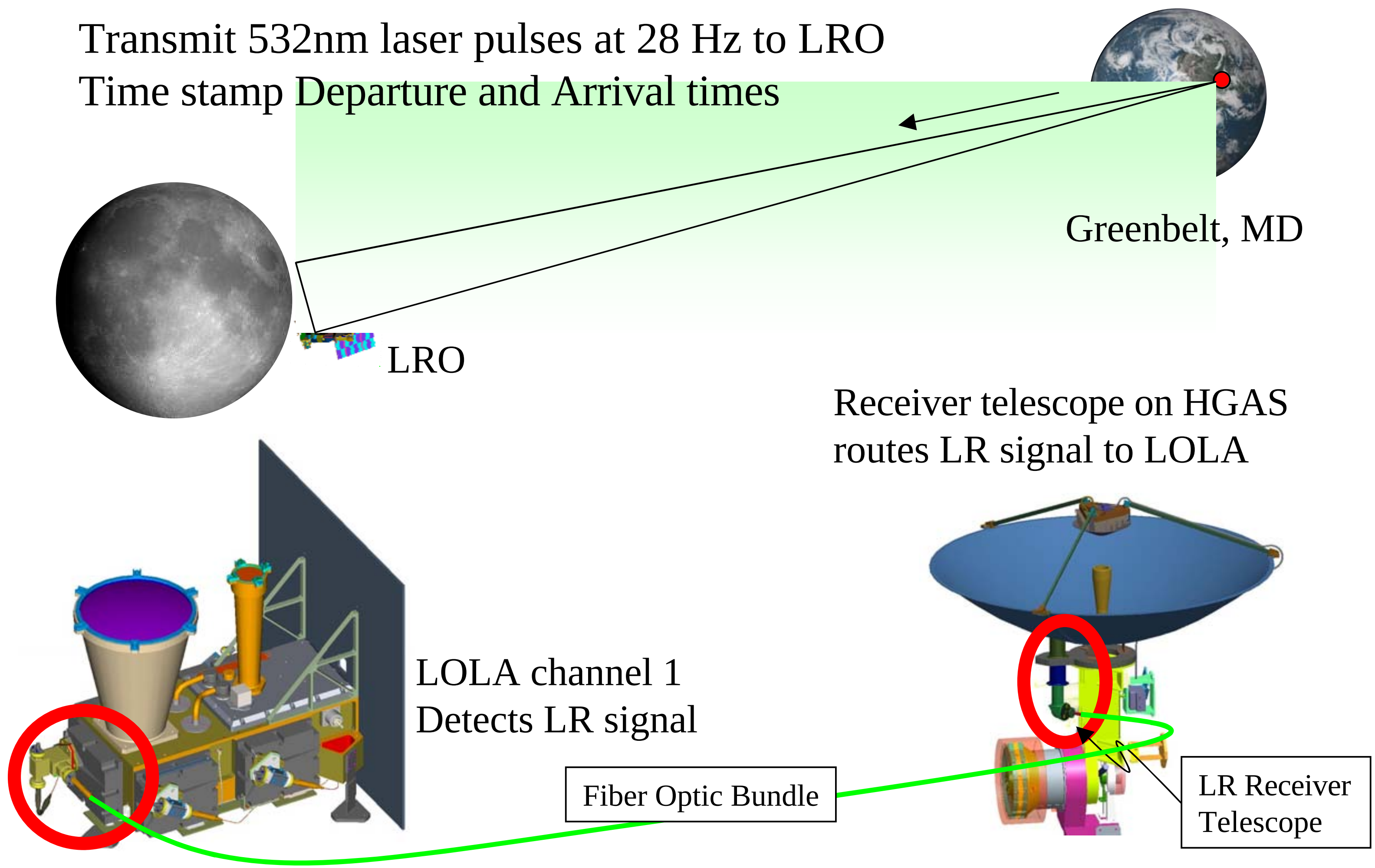


Crossovers occur about every 1 km in longitude and 3 deg in latitude at equator

One-way Laser Ranging to LRO, with LOLA altimetry, enables far-side gravity field determination

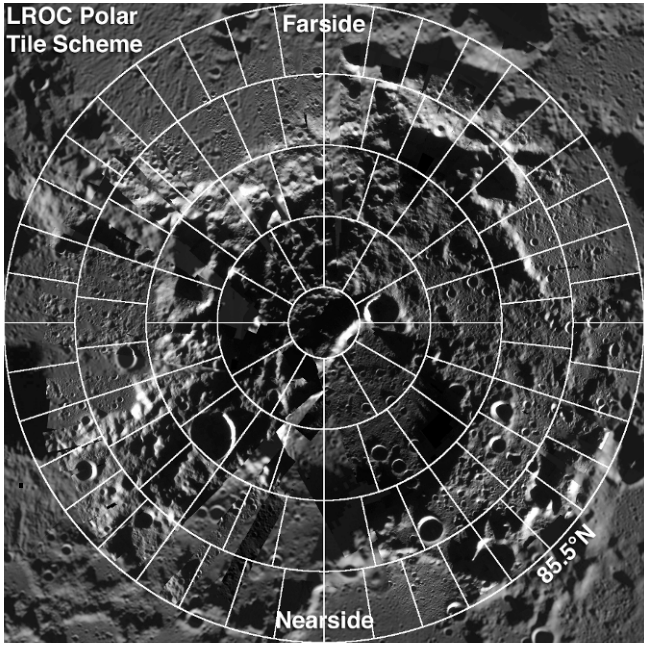
Opportunities for global set of ground stations
(opportunities for international collaboration)

Transmit 532nm laser pulses at 28 Hz to LRO
Time stamp Departure and Arrival times



Landing Site Safety: LROC Narrow Angle Cameras (NACs) will Improve Mapping Resolution to Landing Craft Scale

- **LROC (PI Mark Robinson) NAC images 25x higher resolution than current best data**
  - **Current best image resolves 25m scale features, NACs will resolve 1m scale features**
- The NAC 0.5 m/pixel polar mosaic will be processed into 103 tiles. Achieved in about 30 days
- LROC images will be gridded to LOLA improved geodetic system
- **LRO targeting workshop planned for Spring 2007 - coordination with other missions**

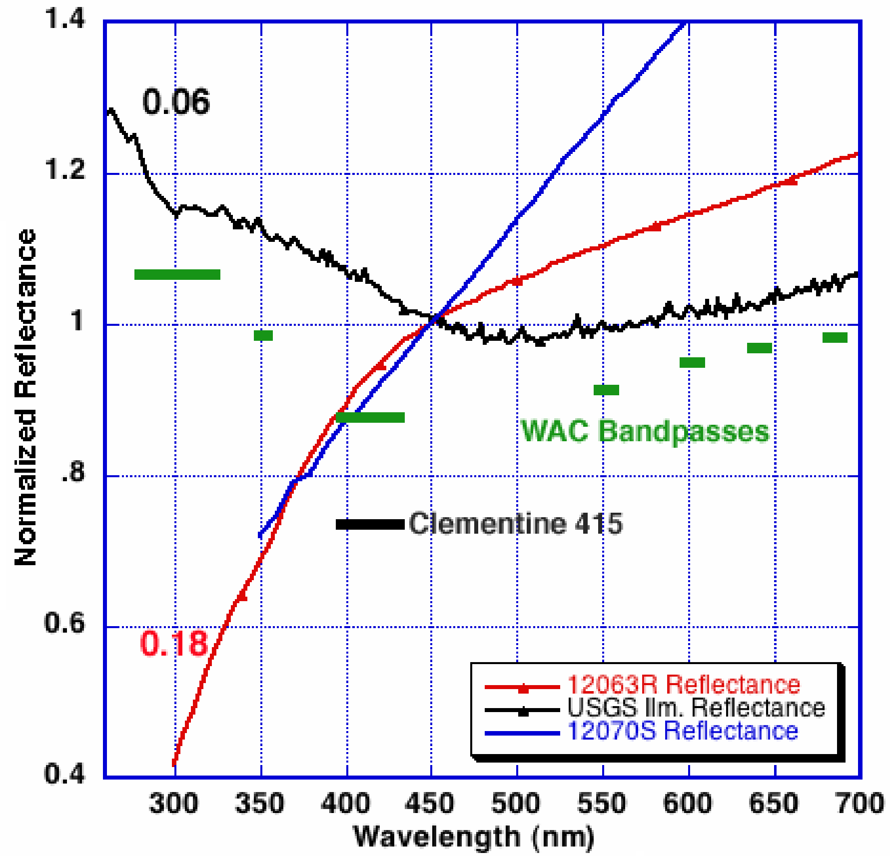


NAC polar mosaic tiles ~ 15 km x 30 km containing approximately 2 billion pixels.

LROC WAC Multispectral Mapping

- WAC UV / Visible
  - 315, 360, 415, 560, 600, 640, 680 nm
  - Global visible map at 100 m/pixel
  - Global UV map at 400 m/pixel
  - Map TiO_2 soils (hold H, He)
  - Pyroclastic glasses (volatiles)
  - Olivine (magmatic processes)
- Meshes with Clementine 100-200 m/pixel (415, 750, 900, 950, 1000)

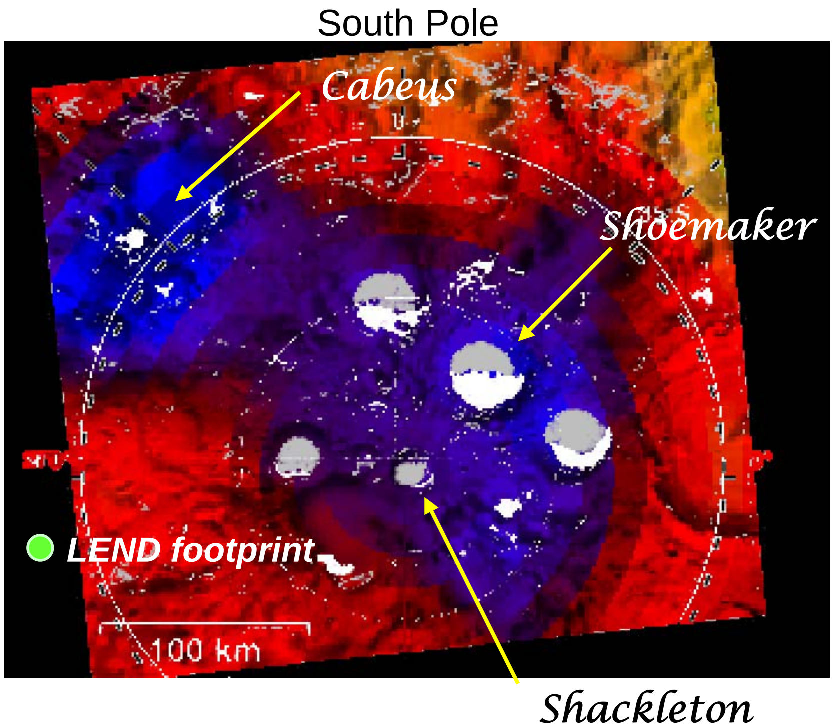
- **What opportunities are afforded for different spectral comparisons on all missions?**



LRO WAC bandpasses and key lunar mineral spectra

Locate Resources: LEND measurements locate hydrogen concentrations

- LEND (PI Igor Mitrofanov) improves spatial resolution from 140km to 10km to locate areas of high hydrogen concentration
- LEND footprint smaller than the Permanently Shadowed Regions of interest
- Improves sensitivity of measurements in cold spots
- Enables site selection
- **Opportunities for different measurement techniques to address hydrogen/ice in regolith**

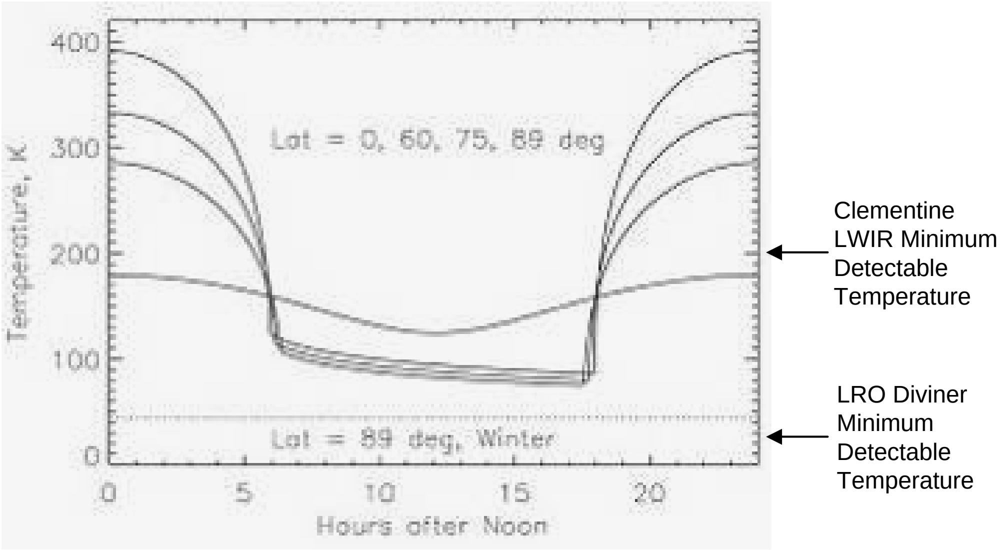


White areas represent permanently shadowed regions from as determined from ground based radar and overlaid on Lunar Prospector hydrogen concentrations

Locate Resources: Diviner Thermal Characterization

- **Diviner will characterize the global Lunar thermal environment**
  - Rock abundance
  - Map cold trap locations
  - Assess potential for Lunar volatiles
    - Diviner data in conjunction with LOLA topographic data, LROC illumination data and models
  - Direct measurement of diurnal temperature swing

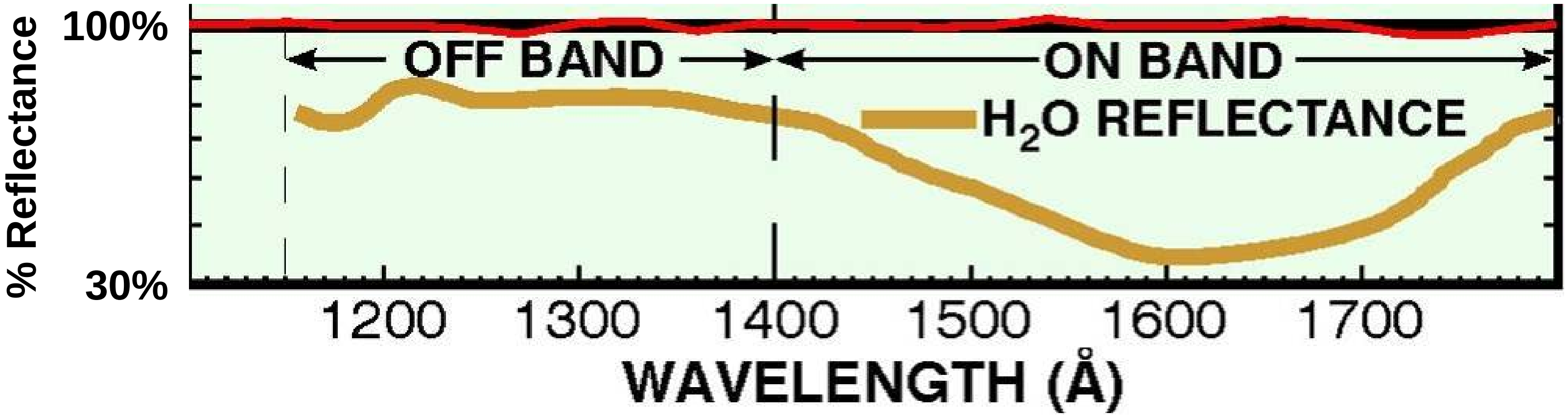
Clementine LWIR Daytime Thermal Image (200m /pixel)



Water ice is stable against sublimation until a temperature of ~100 K

Locate Resources: LAMP sees surface ice and into dark craters

- LAMP (PI Alan Stern) has a diagnostic UV absorption feature to identify pure water ice on the Lunar surface
  - H_2O frost has a distinct broad UV absorption near 1600 Å



- Images permanently shadowed regions at ~500m resolution using ambient UV illumination

Are the unique advantages of LAMP UV capability of interest to other missions?

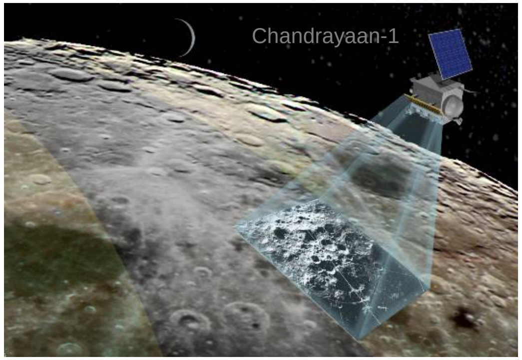
Life in Space Environment

- CRaTER (PI Harlan Spence) will measure the Linear Energy Transfer (LET) spectra behind tissue equivalent material
  - LET spectra is the missing link connecting Galactic Cosmic Rays and Solar Energetic Particles to potential tissue damage
- LEND contributes by providing knowledge of the neutron radiation environment
- **What synergy arises from the cross-pollination of all radiation measurements have? - e.g. longer span of coverage through a solar cycle**

Mini-RF Lunar Technology Demonstrations

PI: Stu Nozette
LRO POC: Keith Raney

SAR Imaging (Monostatic and Bistatic)



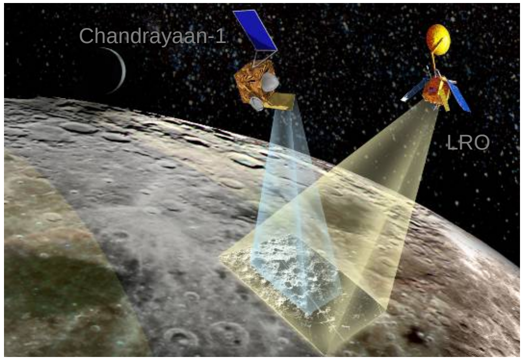
Monostatic imaging in S-band to locate and resolve ice deposits on the Moon.

Communications Demonstrations

Component Qualification

Monostatic imaging in S-band and X-band to validate ice deposits discoveries on the Moon

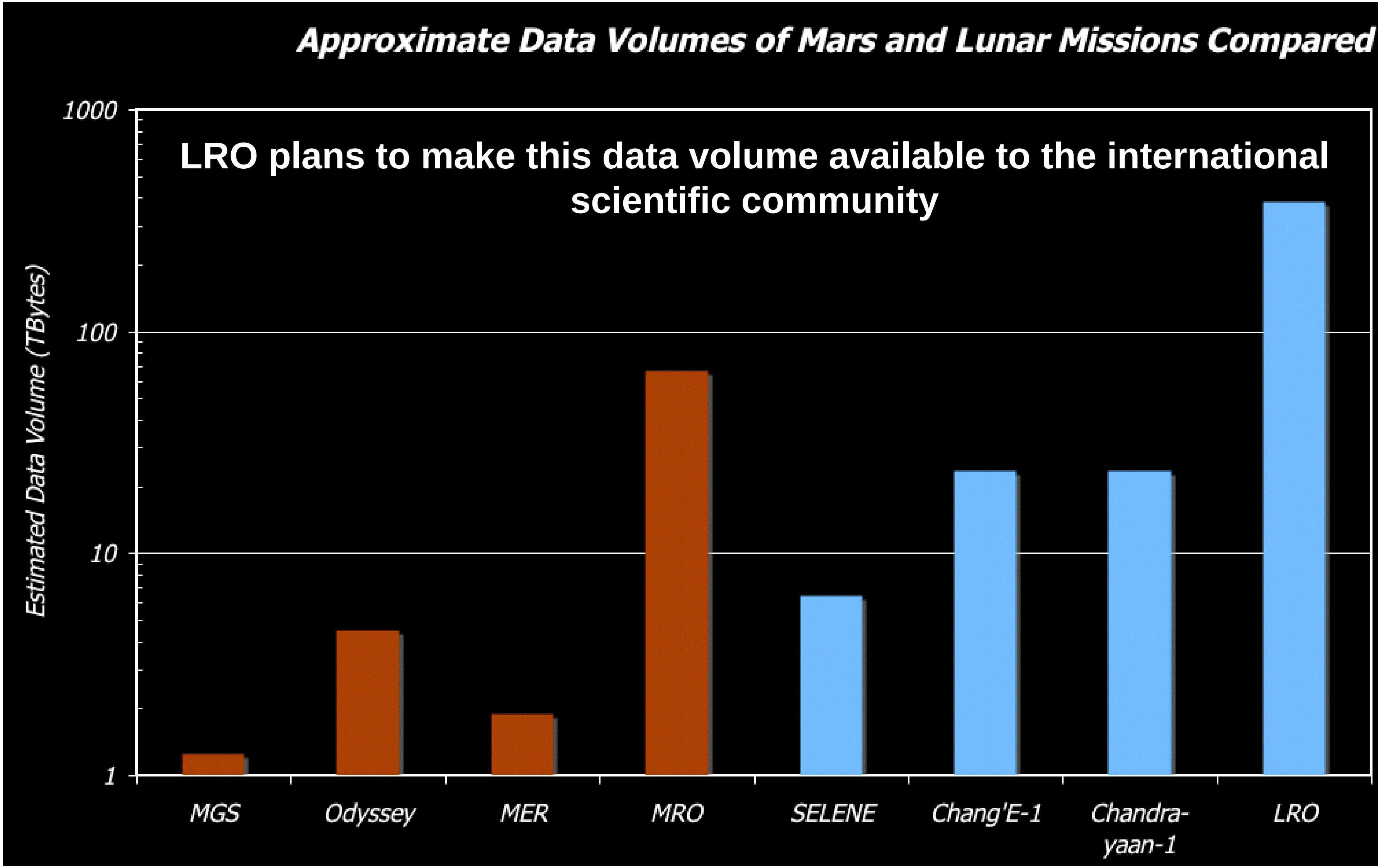
X-Band Comm Demo



Coordinated, bistatic imaging in S-band, to be compatible with the Chandrayaan-1 and LRO spacecraft, can unambiguously resolve ice deposits on the Moon

Other Coordinated Tech Demos: e.g ranging, rendezvous, gravity

Expected LRO Data Volumes



International Lunar Missions: Possibilities of Cross Cultural and International EPO

- Introduction and acknowledgement of present EPO leads
- The opportunity to engage a world wide population with the current global lunar exploration effort is extraordinary
- The impact of this new era in lunar exploration can also be seen in light of historical analogs to ages of exploration – and the impact the new era can have in motivating youths around the world
- Education and Public Outreach (EPO) should be an important dimension of LRO, and all missions
  - The NASA Exploration Mission Systems Directorate (ESMD), Lunar Precursor Robotic Program (LPRP) and LRO will need to implement an integrated strategy for seizing this unique opportunity
  - We are drawing on NASA’s Science Missions Directorate (SMD) experiences by leveraging its strengths in advancing EPO as an integral part of a NASA mission
  - We are introducing an opportunity to develop international EPO collaborations at the breakout tomorrow afternoon